

## Applied Linear Models with SAS

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This textbook for a second course in basic statistics for undergraduates or first-year graduate students introduces linear regression models and describes other linear models including Poisson regression, logistic regression, proportional hazards regression, and nonparametric regression. Numerous examples drawn from the news and current events with an emphasis on health issues illustrate these concepts.

Assuming only a pre-calculus background, the author keeps equations to a minimum and demonstrates all computations using SAS. Most of the programs and output are displayed in a self-contained way, with an emphasis on the interpretation of the output in terms of how it relates to the motivating example. Plenty of exercises conclude every chapter. All of the datasets and SAS programs are available from the book's Web site, along with other ancillary material.

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## Contents

<i>Preface</i>	<i>page</i> ix
<i>Acknowledgments</i>	xiii
1 Introduction	1
1.1 What Is Statistics?	1
1.2 Statistics in the News: The Weather Map	4
1.3 Mathematical Background	6
1.4 Calculus	7
1.5 Calculus in the News: New Home Sales	9
1.6 Statistics in the News: IMF Loans and Tuberculosis	11
1.7 Exercises	13
2 Principles of Statistics	21
2.1 Binomial Distribution	21
2.2 Confidence Intervals and the Hubble Constant	25
2.3 Normal Distribution	26
2.4 Hypothesis Tests	30
2.5 The Student t-Test	34
2.6 The Chi-Squared Test and $2 \times 2$ Tables	42
2.7 What Are Degrees of Freedom?	47
2.8 SAS, in a Nutshell	49
2.9 Survey of the Rest of the Book	51
2.10 Exercises	52
3 Introduction to Linear Regression	58
3.1 Low-Birth-Weight Infants	58
3.2 The Least Squares Regression Line	59
3.3 Regression in SAS	63
3.4 Statistics in the News: Future Health Care Costs	65
3.5 Exercises	66

**vi**      **Contents**

4	Assessing the Regression	75
4.1	Correlation	75
4.2	Statistics in the News: Correlations of the Global Economy	77
4.3	Analysis of Variance	78
4.4	Model Assumptions and Residual Plots	81
4.5	Exercises	84
5	Multiple Linear Regression	90
5.1	Introductory Example: Maximum January Temperatures	90
5.2	Graphical Displays of Multivariate Data	94
5.3	Leverage and the Hat Matrix Diagonal	96
5.4	Jackknife Diagnostics	99
5.5	Partial Regression Plots and Correlations	102
5.6	Model-Building Strategies	105
5.7	Exercises	110
6	Indicators, Interactions, and Transformations	120
6.1	Indicator Variables	120
6.2	Synergy in the News: Airline Mergers	127
6.3	Interactions of Explanatory Variables	128
6.4	Transformations	132
6.5	Additional Topics: Longitudinal Data	137
6.6	Exercises	138
7	Nonparametric Statistics	150
7.1	A Test for Medians	150
7.2	Statistics in the News: Math Achievement Scores	153
7.3	Rank Sum Test	155
7.4	Nonparametric Methods in SAS	156
7.5	Ranking and the Healthiest State	157
7.6	Nonparametric Regression: LOESS	160
7.7	Exercises	163
8	Logistic Regression	169
8.1	Example	169
8.2	The Logit Transformation	170
8.3	Logistic Regression in SAS	173
8.4	Statistics in the News: The New York Mets	177
8.5	Key Points	178
8.6	Exercises	179
9	Diagnostics for Logistic Regression	187
9.1	Some Syntax for <code>proc logistic</code>	188
9.2	Residuals for Logistic Regression	190

<b>vii</b>	<b>Contents</b>	
	9.3 Influence in Logistic Regression	193
	9.4 Exercises	197
10	Poisson Regression	204
	10.1 Statistics in the News: Lottery Winners	204
	10.2 Poisson Distribution Basics	204
	10.3 Regression Models for Poisson Data	206
	10.4 Statistics in the News: Attacks in Iraq	208
	10.5 Poisson Regression in SAS	209
	10.6 Exercises	215
11	Survival Analysis	225
	11.1 Censoring	225
	11.2 The Survival Curve and Its Estimate	227
	11.3 The Log-Rank Test and SAS Program	232
	11.4 Exercises	235
12	Proportional Hazards Regression	237
	12.1 The Hazard Function	237
	12.2 The Model of Proportional Hazards Regression	239
	12.3 Proportional Hazards Regression in SAS	241
	12.4 Exercises	243
13	Review of Methods	247
	13.1 The Appropriate Method	247
	13.2 Other Review Questions	249
	<i>Appendix: Statistical Tables</i>	255
	A.1 Normal Distribution	255
	A.2 Chi-squared Tables	257
	<i>References</i>	259
	<i>Selected Solutions and Hints</i>	263
	<i>Index</i>	269

## Preface

Linear models are a powerful and useful set of methods in a large number of settings. Very briefly, there is some outcome measurement that is very important to us and we want to explain variations in its values in terms of other measurements in the data. The heights of several trees can be explained in terms of the trees' ages, for example. It is not a straight line relationship, of course, but knowledge of a tree's age offers us a large amount of explanatory value. We might also want to take into account the effects of measurements on the amount of light, water, nutrients, and weather conditions experienced by each tree. Some of these measurements will have greater explanatory value than others and we may want to quantify the relative usefulness of these different measures. Even after we are given all of this information, some trees will appear to thrive and others will remain stunted, when all are subjected to identical conditions. This variability is the whole reason for statistics existing as a scientific discipline. We usually try to avoid the use of the word "prediction" because this assumes that there is a cause-and-effect relationship. A tree's age does not directly cause it to grow, for example, but rather, a cumulative process associated with many environmental factors results in increasing height and continued survival. The best estimate we can make is a statement about the behavior of the average tree under identical conditions.

Many of my students go on to work in the pharmaceutical or health-care industry after graduating with a masters degree. Consequently, the choice of examples has a decidedly health/medical bias. We expect our students to be useful to their employers the day they leave our program so there is not a lot of time to spend on advanced theory that is not directly applicable. Not all of the examples are from the health sciences. Diverse examples such as the number of lottery winners and temperatures in various US cities are part of our common knowledge. Such examples do not need a lengthy explanation for the reader to appreciate many of the aspects of the data being presented.

How is this book different? The mathematical content and notation are kept to an absolute minimum. To paraphrase the noted physicist Steven Hawking, who

has written extensively for the popular audience, every equation loses half of your audience. There is really no need for formulas and their derivations in a book of this type if we rely on the computer to calculate quantities of interest. Long gone are the days of doing statistics with calculators or on the back of an envelope. Students of mathematical statistics should be able to provide the derivations of the formulas but they represent a very different audience. All of the important formulas are programmed in software so there is no need for the general user to know these.

The three important skills needed by a well-educated student of applied statistics are

1. Recognize the appropriate method needed in a given setting.
2. Have the necessary computer skills to perform the analysis.
3. Be able to interpret the output and draw conclusions in terms of the original data.

This book gives examples to introduce the reader to a variety of commonly encountered settings and provides guidance through these to complete these three goals. Not all possible situations can be described, of course, but the chosen settings include a broad survey of the type of problems the student of applied statistics is likely to run into.

What do I ask of my readers? We still need to use a lot of mathematical concepts such as the connection between a linear equation and drawing the line on  $X - Y$  coordinates. There will be algebra and special functions such as square roots and logarithms. Logarithms, while we are on the subject, are always to the base  $e$  ( $\approx 2.718$ ) and not base 10.

We will also need a nodding acquaintance with the concepts of calculus. Many of us may have taken calculus in college, a long time ago, and not had much need to use it in the years since then. Perhaps we intentionally chose a course of study that avoided abstract mathematics. Even so, calculus represents an important and useful tool. The definition of the derivative of a function (What does this new function represent?) and integral (What does *this* new function represent?) are needed although we will never need to actually find a derivative or an integral. The necessary refresher to these important concepts is given in Section 1.4.

Also helpful is a previous course in statistics. The reader should be familiar with the mean and standard deviation, normal and binomial distributions, and hypothesis tests in general and the chi-squared and t-tests specifically. These important concepts are reviewed in Chapter 2 but an appreciation of these important ideas is almost a full course in itself. There is a large reliance on p-values in scientific research so it is important to know exactly what these represent.

There are a number of excellent general-purpose statistical packages available. We have chosen to illustrate our examples using SAS because of its wide acceptance and use in many industries but especially health care and pharmaceutical. Most of the examples given here are small, to emphasize interpretation and encourage practice. These datasets could be examined by most software packages. SAS, however, is



capable of handling huge datasets so the skills learned here can easily be used if and when much larger projects are encountered later.

The reader should already have some familiarity with running SAS on a computer. This would include using the editor to change the program, submitting the program, and retrieving and then printing the output. There are also popular point-and-click approaches to data analysis. While these are quick and acceptable, their ease of use comes with the price of not always being able to repeat the analysis because of the lack of a printed record of the steps that were taken. Data analysis, then, should be reproducible.

We will review some of the basics of SAS but a little hand-holding will prevent some of the agonizing frustrations that can occur when first starting out. Running the computer and, more generally, doing the exercises in this book are a very necessary part of learning statistics. Just as you cannot learn to play the piano simply by reading a book, statistical expertise, and the accompanying computer skills, can only be obtained through hours of active participation in the relevant act. Again, much like the piano, the instrument is not damaged by playing a wrong note. Nobody will laugh at you if you try something truly outlandish on the computer either. Perhaps something better will come of a new look at a familiar setting. Similarly, the reader is encouraged to look at the data and try a variety of different ways of looking, plotting, modeling, transforming, and manipulating. Unlike a mathematical problem with only one correct solution (contrary to many of our preconceived notions), there is often a lot of flexibility in the way statistics can be applied to summarize a set of data. As with yet another analogy to music, there are many ways to play the same song.

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The DASL (pronounced “dazzle”) StatLib library maintained at Carnegie Mellon University is a great resource and provided data for many examples and exercises contained here. Ed Tufte’s books on graphics have taught me to look at data more carefully. His books are highly recommended.

I am grateful to *The New York Times* for their permission to use many graphic illustrations.

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DANIEL ZELTERMAN  
Hamden, CT  
August 25, 2009

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